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EDITORIAL

Focus on terahertz plasmonics*

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Abstract

Plasmonics is one of the growing fields in modern photonics that has garnered increasing interest over the last few years. In this focus issue, the specific challenges concerning terahertz plasmonics have been addressed and most recent advances in this specific field have been highlighted. The articles demonstrate the diversity and the opportunities of this rich field by covering a variety of topics ranging from the propagation of surface plasmon polaritons (SPPs) on artificially structures surfaces, 2D manipulation of surface plasmons and SPPs, plasmonic focusing, plasmonic high-Q resonators for sensing applications, plasmonically enhanced terahertz antennas to terahertz field manipulation by use of plasmonic structures. The articles substantiate the impact of plasmonics and its great innovative potential for terahertz technology.

Plasmonics has been one of the most intriguing research fields of photonics during the last few years. The specific charms of plasmonics are manifold. From a basic scientific point of view, the hybridized interaction between electromagnetic waves and metals involves a great variety of fundamental physical effects that deserve in-detail investigation and consideration. Moreover, when directing our attention to industrial applications, the innovation potential of plasmonics is tremendous with respect to the development of novel nanophotonic devices.

Especially in terahertz (THz) technology, which copes with strong limitations regarding the functionality of existing photonic devices, plasmonic approaches that open up new routes towards innovative THz photonics could greatly leverage the applicability of modern THz measurement systems. In this context, localized surface plasmons, and especially surface plasmon polaritons can play a major role in THz generation, waveguiding, subwavelength focusing and imaging as well as subwavelength guiding of THz waves on plasmonic network chips.

It is obvious, that one of the key features of plasmonics lies in the ability to achieve subwavelength spatial localization of the electromagnetic field. Here, strong field confinement requires sufficient spectral dispersion in the dielectric properties of metals. This naturally occurs near the plasma frequency, which is typically in the ultraviolet spectral range. In order to obtain strongly localized hybridized fields in the THz regime, a number of different approaches can be followed. First, highly doped materials, including semiconductors and conducting polymers with plasma frequencies in the far infrared, can be used instead of metals. Second, the metals can be structured on a subwavelength scale, which basically dilutes the metal, resulting in an artificial increase of the field penetration of so-called spoof plasmons into the metal. Third, thinking in more general terms, plasmonic meta-surfaces can be specifically designed to tailor the dispersion and the confinement of waves traveling along their surface. Moreover, Goubau lines have proven to be almost ideally suited for subwavelength guiding of THz surface waves.

This focus issue on THz plasmonics features a total of seven articles that demonstrate the diversity and broad opportunities related to this highly intriguing research field. Two of the research papers deal with the

* In memory of Professor Mario Sorolla Ayza.

propagation of THz surface waves and surface plasmon polaritons. Kumar *et al* experimentally demonstrated the propagation of a tightly confined THz surface mode on a silicon surface patterned with an array of silicon pillars [1]. By changing the geometrical parameters of the array structure the authors could spatially control the electromagnetic properties of the observed surface waves. In a similar context, Tsiatmas *et al* demonstrated the superior properties of superconductors with respect for low loss and long distance propagation of THz surface plasmon polaritons [2]. Both articles corroborate the importance and necessity to advance our technological approaches and capabilities of generating, guiding and controlling strongly confined THz surface plasmon polaritons and surface waves on a subwavelength scale in order to pave the way to integrated THz networks and circuits.

While the research articles mentioned above basically cover the topic of one-dimensional surface plasmon polariton guiding and control, the papers of Waselikowski *et al* and Liu *et al* are concerned with two-dimensional manipulation of surface plasmon polaritons. Waselikowski *et al* mapped the frequency-dependent focusing of surface plasmon polaritons of radially polarized THz pulses in the center of a metal disc caused by constructive interference in the disc center [3]. They also investigated and proved the functionality of the plasmonic lens for linearly polarized THz light. J Liu *et al* fabricated a THz bandpass resonator by use of a parallel-plate waveguide with corrugated plates on one output facet and a mirror on the other end. After geometric optimization they observed 100% reflectivity at the patterned output facet for narrow frequency range, thus being able to devise a high Q THz subwavelength resonator [4]. Schaafsma *et al* used a single plasmonic bowtie antenna consisting of two n-doped silicon monomers with triangular shape and facing apexes for resonant extinction of THz radiation at the output facet of a conically tapered waveguide [5]. The field enhancement observed in high Q resonators or in devices with plasmonic focusing to the subwavelength range is of great importance for high signal-to-noise THz sensing and imaging of small substances or weakly absorbing material.

Berry *et al* demonstrated that plasmonic structures not only considerably advance the THz sensing technology, but also can be used to dramatically improve the efficiency of photoconductive THz emitters [6]. By means of a nanoscale plasmonic grating, the authors successfully reduced the path of the photo-excited carriers in the photoconductive THz antenna. This is an interesting and cost-effective alternative to short-carrier lifetime semiconductors for efficient THz generation, making short-carrier lifetime semiconductors obsolete. As a further advantage, such antennas allow an enlargement of the active area without increasing the capacitive load and preventing carrier screening and thermal breakdown at high optical pump powers of the antenna. Such innovative antenna designs are of utmost significance when it comes to an urgently required optimization of THz photoconductive antennas pumped at telecommunication wavelengths.

Finally, the focus issue covers the topic of THz field manipulation by use of plasmonic structures. Cong *et al* reported linear-to-linear polarization rotation and linear-to-elliptic polarization conversion of THz electromagnetic waves using a double-ring-chain plasmonic metamaterial [7]. This work emphasizes the important role of plasmonic metamaterials for the control of THz electromagnetic fields and their potential for the development of novel optical devices.

The articles of the focus issue highlight the latest advances in the highly competitive field of THz plasmonics and reveal important aspects of the fascinating physics behind THz wave interaction with plasmonic structures. They evidence the great potential for harnessing the benefits of this technology for the design and implementation of innovative THz networks on a chip, optimization of THz antennas, control of electromagnetic fields, development of compact THz optics and sensing with subwavelength spatial resolution.

We dedicate this focus issue to the legacy of Professor Mario Sorolla Ayza, who passed away on 1 November 2012. We will keep him in memory as a great researcher, conveyor of young scientists and a fantastic person.

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